NETWORK PROGRAMMING OF JOINT TACTICAL RADIO SYSTEM RADIOS

Donald R. Stephens, Cinly Magsombol, Norman Browne
Joint Program Executive Office (JPEO), Joint Tactical Radio Systems
San Diego, CA

ABSTRACT

The Joint Tactical Radio System (JTRS) program is developing a set of Mobile Ad-hoc NETworking (MANET) waveforms, to provide the last tactical mile connectivity to the Global Information Grid (GIG). JTRS networking services provide an Internet Protocol (IP) networking stack and networking services that operate at Open Systems Interconnection (OSI) Layer 3 and below. Developers program the networking services using the Internet Engineering Task Force (IETF) open standards (i.e. the application and transport layers).

Applications must recognize and account for the different characteristics of the wireless MANET environment in order to assure successful deployments. Design decisions (at the transport and application layers) need to appropriately consider the behavior and performance of tactical wireless networks.

INTRODUCTION

Four new JTRS networking waveforms are currently in development; Wideband Networking Waveform (WNW), Soldier Radio Waveform (SRW), Joint Airborne Networking – Tactical Edges (JAN-TE), and Mobile User Object System (MUOS). The JTRS program is also developing the Enterprise Networking Services (ENS) to provide a common set of networking services to waveforms and user applications. These networking elements will be hosted on the JTRS family of multi-band, multi-mode, software device, programmable/reconfigurable radios to provide a common interoperable IP data transport for net-centric operations.

JTRS extends the GIG to the tactical edge as illustrated in Figure 1. The GIG extension is accomplished by providing an IP-based transport network infrastructure to the warfighter from a backbone connected to a JTRS networking waveform.

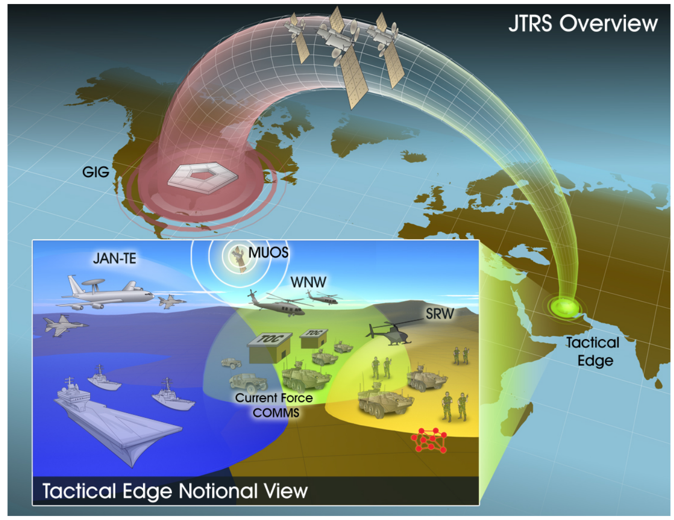

Figure 1 Providing IP Connectivity to the Tactical Edge

Applications that reside outside the radio can be designed to utilize the IP-based JTRS networking infrastructure to support the increasing demand for net-centric information. Applications may include Common Operational Pictures (COPs), collaboration workspaces (e.g. instant messaging), and on-demand services.

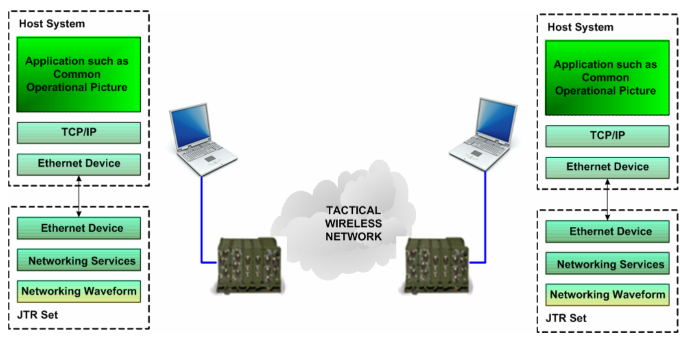

Figure 2 Application data path

As illustrated in Figure 2, different Joint Tactical Radio (JTR) sets will provide various Input/Output (IO) devices over which IP packets will pass between the radio and the application on the host. The radios form a wireless network which will be the 'media' connecting the application(s). As part of the overall wireless net, the JTR sets perform all necessary routing functions. The attached host might be a single laptop connected via a serial or ethernet cable to the JTR, or a node in a wired sub-network behind by the JTR set. From the application perspective, this is no different then being connected to a wired network. The IP stack on the host

978-1-4244-2677-5/08/$25.00 (c)2008 IEEE

and access to the network is the same regardless of the physical medium.

JTRS NETWORKING WAVEFORMS

JTRS networking waveforms are designed to support the networking needs of the ground, maritime/fixed station, and airborne domains as shown in Figure 3. These networking capabilities will integrate to provide Line of Sight (LOS) and Beyond Line Of Sight (BLOS) communications across the warfighting domains.

The Joint Integrated Architecture (JIA) is the collection of integrated architecture views required by DoD 4360.5 and shows how the JTRS Family of Systems interconnects and provides an integrated capability. Figure 4 shows the Operational View for Increment 1 (OV-1).

	2-Apr-08	CIS CHR		Ground Domain					Airborne/Maritime/Fixed		
		MBITR /JEM	(FALCON)	(HMS)				(GMR)	(MIDS)	(AMF)	
	Version 10.4										
	Joint Capability	1 CH Handheld	1 Ch Handheld	Type 2 1-2 CH SFF	Type 1 1-2 CH SFF	2 CH Handheld	2 CH Manpack	4 CH Vehicle	4 CH MIDS-J	2 CH AMF-SA	4 CH AMF-M
Transformational	Joint Networking	-	-	-	-	-	-	WNW	-	WNW	-
		-	-	SRW	SRW	SRW	SRW	SRW	-	SRW	-
		-	-	-	-	-	-	-	JAN-TE	-	-
		-	-	-	-	-	MUOS-A	-	-	MUOS	MUOS
	Enterprise MGR	-	-	ENM	ENM	ENM	ENM	ENM	-	ENM	-
	Enterprise Svcs	-	-	-	ENS	ENS	ENS	ENS	-	ENS	-

Figure 3 JTRS Joint Networking Capabilities

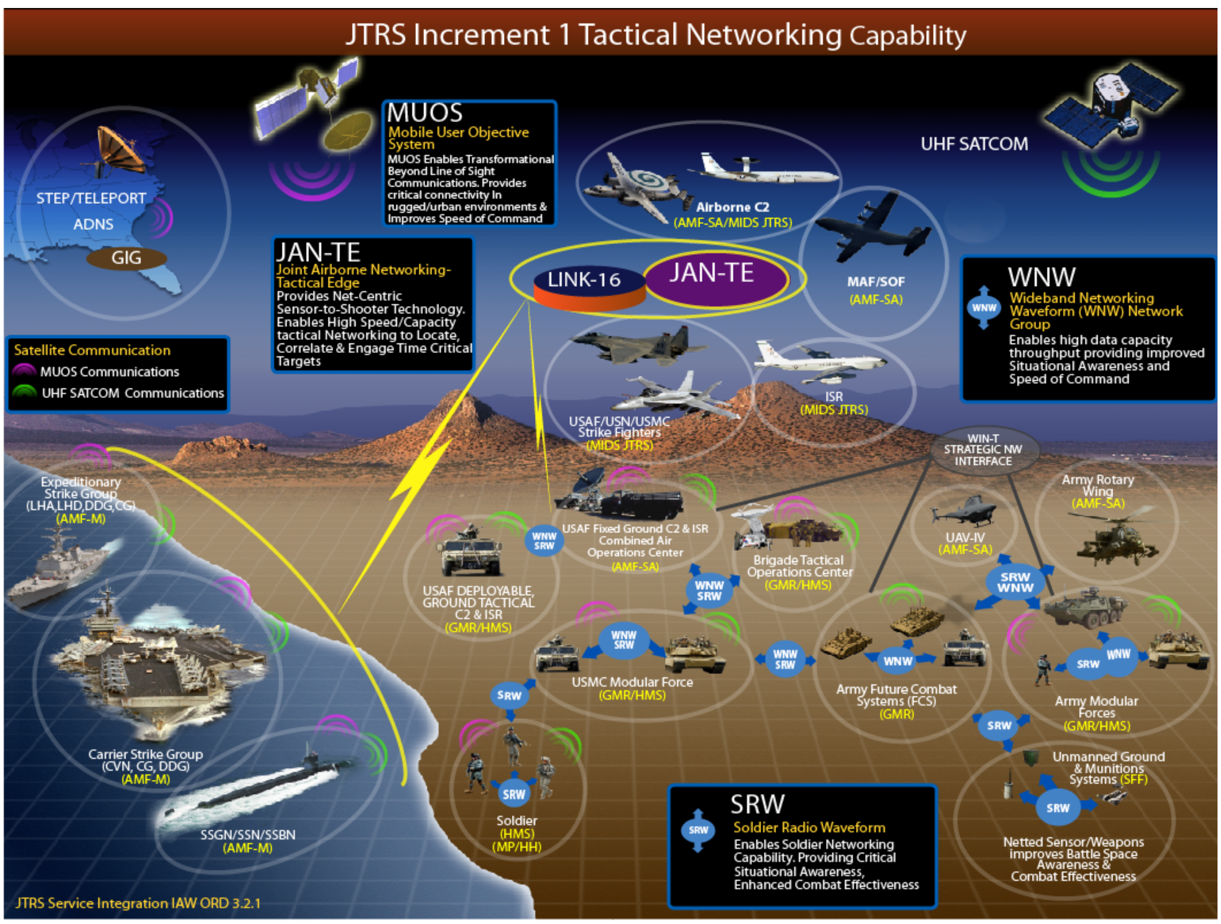

Figure 4 JTRS Integrated Architecture (OV-1)

JTRS networking waveforms encapsulate networking services and protocols defined in the lower 2 layers (i.e. Data Link and Physical) of the seven-layer OSI networking reference model and provide both peer-to-peer communications and multi-conference communications.

Each waveform is based on MANET technology and is designed to handle the unique characteristics of the wireless tactical environment for each domain. MANETs are characterized as having dynamic topologies in which radio nodes are mobile and free to move arbitrarily. They are bandwidth constrained and experience variable capacity links. Other characteristics separating MANET nodes from their wired counterparts include power constraints and increased security threats.

WNW enables high data capacity throughput and provides improved situational awareness and speed of command. It is designed to operate on manned vehicular-based communication systems. The WNW network provides a secure backbone routing infrastructure that passes network traffic within and between ground and airborne domains. It also provides network access to the GIG.

SRW enables data and imagery situational awareness and provides enhanced combat effectiveness. It is designed for the dismounted soldier and battery-operated small form factors that are Size, Weight, and Power (SWaP) constrained. The SRW network is a stub network that carries traffic originating at and/or destined for internal nodes and relies on WNW for backbone routing.

JAN-TE is a specialized networking waveform that provides net-centric sensor-to-shooter technology over the tactical network edge. It is designed to operate on fast moving tactical airborne platforms that require high speed/capacity networking to locate, correlate and engage time critical targets.

MUOS provides critical BLOS connectivity and speed of command for rugged/urban environments. It provides simultaneous voice, data, and video services communication through the MUOS Ultra High Frequency (UHF) satellite constellation and accompanying ground segment.

ENTERPRISE NETWORKING SERVICES

The four networking waveforms described above provide a collection of individual networking services. JTRS Enterprise Network Services (ENS) will provide a common set of network services and capabilities for the JTR sets defined in layer 3 (i.e. Network) of the seven-layer OSI. Figure 5 illustrates the types of networking capabilities that are available to the JTRS networking waveforms as well as external applications. These services have been selected and tailored specifically for tactical wireless environment. Usage of standardized Application Programming Interfaces (APIs) between ENS and the waveforms allow very different waveforms such as WNW or MUOS to access the same services. ENS will provide a common API and code base for networking services instead of embedding them within the individual waveforms.

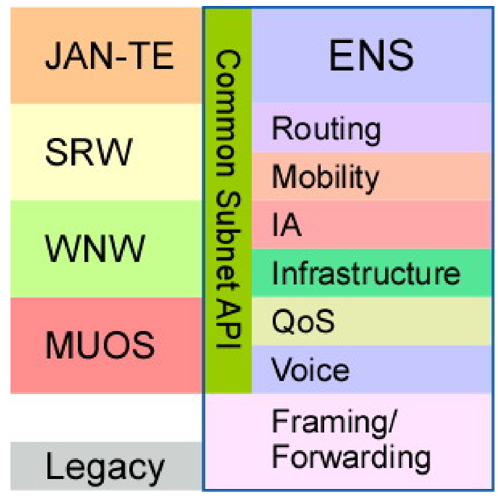

Figure 5 Encapsulating Network Services for JTRS

The available networking services listed in Table 1 supplement and collaborate with the MANET routing capabilities provided by the waveforms. Because the JTR sets provide connectivity to the last tactical mile, networking services must be capable of healing a fragmented subnet through the JTRS network, provided that end-to-end connectivity through a waveform can be established.

Table 1 Common Networking Services

Service Type	Protocols
Internet Protocol Support	IPv4, ICMP, IGMP
Internet Routing	Unicast, Multicast, Inter & Intra domain
QoS	DiffServ, IntServ, marking, policing, admission control, shaping, scheduling
Mobility Support	Inter & Intra Domain
Network Infrastructure Services	DNS, DHCP, NTP, ARP
Networked Applications	Voice over IP, Position Reporting

JTRS networking services support IPv4 and internet protocols such as Internet Control Message Protocol (ICMP) and Internet Group Management Protocol (IGMP). ICMP permits applications to send in-band control messages and utilize limited standard functions such as ping. This protocol is primarily used to permit external routers to communicate with the JTR set. IGMP permits membership management of multicast groups to allow both sources and clients to advertise their availability or need for content.

The Enterprise Network Services will provide adaptation between the native waveform routing services (that provide peer-to-peer and multi-conference communications) and the traditional IP's unicast or multicast services. As will be discuss later, multicast has increased importance for wireless networks because of bandwidth constraints.

Similarly, since the wireless bandwidth in the tactical warfare environment is limited, JTRS networking services provide social awareness through Quality of Service (QoS) mechanisms to allow appropriate prioritization of the bandwidth by the waveforms. Support of Differentiated Services (DiffServ) enables applications to mark the classification of data packets on a packet-by-packet basis. Networking services then map the quality of service classes into the native waveform QoS and service priorities. Traffic assigned to higher classes is allocated preferential QoS latency and reliability. Limited implementation of Integrated Services (IntServ) is also provided to applications. This fine-grained QoS mechanism is useful to routers connected externally to the JTR Set.

Mobile platform movement of JTR sets is supported by JTRS networking services and connectivity is maintained as individual radios move among different waveform subnets. The underlying MANET capability of the waveform is complemented by networking services, which adapt to changing waveform subnets.

JTRS networking services provide transparent address resolution between the networks connected to the JTR Set and the waveform's subnets as illustrated in Figure 6. This support of Address Resolution Protocol (ARP) decouples address assignments on the GIG from the addressing of JTR Sets and their subnets. Additional network infrastructure services include Domain Name Service (DNS) which allows users to communicate using host names instead of IP addresses. Dynamic Host Configuration Protocol (DHCP) configures clients connected to the JTR Set. Network Time Protocol (NTP) supplies Global Positioning System (GPS) time services to clients attached to the JTR Set. This information facilitates COP data analysis and filtering.

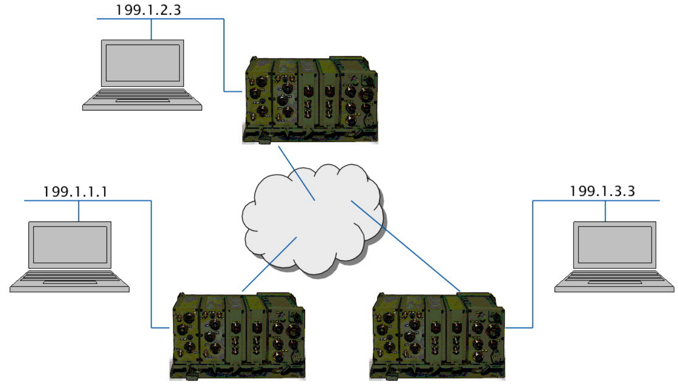

Figure 6 Address Resolution Provided by Networking Services

In addition to the network services, the JTR Set will provide additional network applications that can be utilized by external applications connected to the radio. The first planned application is Packet Voice Services. A refinement of Voice over IP (VoIP) for wired services, the Packet Voice Services will provide the warfighter's preferred push-to-talk netted communications as well as traditional peer-to-peer communications. Position reporting is another application that can be provided by networking services to utilize the GPS services within the JTR set and provide low-latency position reporting through the SiS waveforms. Application support such as voice and position reporting allow external applications to have access to services that would otherwise require direct implementation.

The network services stack is illustrated in Figure 7. Routing is provided for the wired intranet connected to the JTR Set through the Ethernet port as well as to the intranets. The intranets created by the waveforms have a Signal-in-Space (SiS) interface unique to that waveform. The SiS for WNW is different than the SiS for Tactical Targeting Network Technology (TTNT) waveform, SRW, or MUOS. The intranets themselves are different, but the Enterprise Network Services will provide adapters to offer seamless routing to applications connected to the JTR Set.

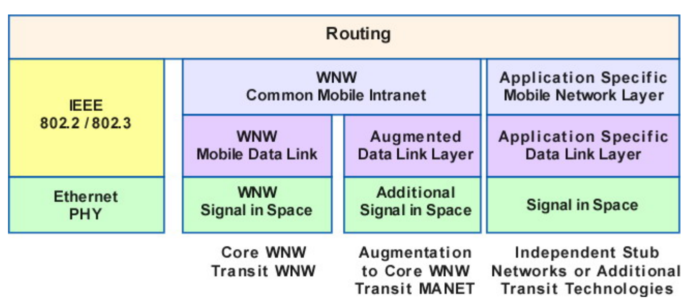

Figure 7 Network Services Stack

CONNECTING EXTERNAL APPLICATIONS

One of the main reasons for employing a TCP/IP infrastructure is to isolate the application residing on a host system from the specifics of the network. This allows network changes without having to re-write or re-compile the host application software. While this holds true in general for the wireless network domain, there are transport specifics that could impact the application.

The wireless environment demands that the application developer consider elements that would be typically outside the scope in traditional network programming. Host systems, and their JTR sets, will be most frequently deployed in mobile platforms: ground vehicles, aircraft, ships, and individual [dismounted] war-fighters. Even for stationary nodes, such as an Operations Center, communications will be with mobile elements. That mobility means the network lacks the sort of stability and reliability associated with more familiar terrestrial links.

An application may expect or require certain transport characteristics such as bandwidth, latency, or jitter. If these characteristics (which are typically taken for granted in the wired world) are not met, how will the application behave? Will it fail – gracefully or not? Or will the application adapt to the offered quality of service and continue to function albeit in a reduced mode? If the application is a client-server based architecture, where the server is located becomes a significant concern.

The following explores some of the considerations an external application must incorporate in their design when connecting to the JTRS network infrastructure as illustrated in Figure 8.

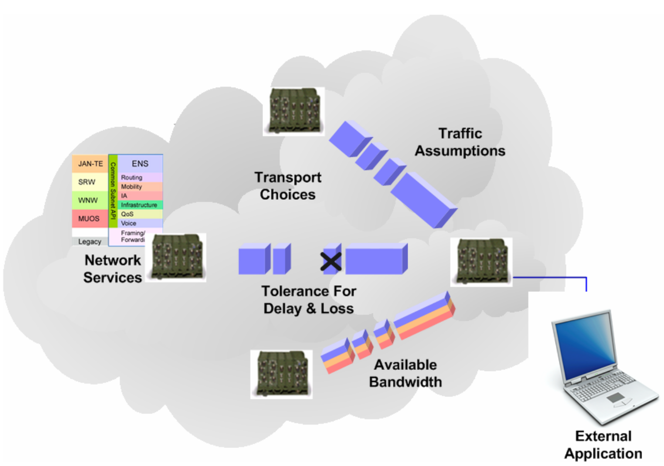

Figure 8 Application Considerations

AVAILABLE BANDWIDTH

Wireless networks will have a significantly lower/limited bandwidth capacity than their hardwired counterparts. Care must be exercised in how an application uses the available bandwidth which is also shared between other applications. Sending relatively large amount of data between nodes may not be the most feasible or efficient way to share data. The application must consider other ways of providing this information. For example, if a large portion of the data to be shared is to remain unchanged, it would be less bandwidth costly to design the application to send the necessary updates instead of the entire data.

TOLERANCE FOR DELAY AND LOSS

Tactical wireless environments comprise of peer-to-peer communications with a limited, if any, wired infrastructure. Mobility of the wireless nodes will cause link variability in both availability and rate/quality. This will often lead to packet loss. In fact, previous Department of Defense (DOD) experiments in wireless networking indicate packet losses (at the application layer) are typically in the double digits (10% or more). Applications need to be designed to allow for or recover from loss generated by the tactical wireless environment. As an example, should the application store the data so that information can be recovered from a loss? If so, where should this information be stored? The application will need to look at specific characteristics of the wireless link to determine how much, how long, or how often this storage would need to occur.

TRANSPORT CHOICES

An application must also consider the environment when matching its architecture with a transport protocol. Transport Control Protocol (TCP) provides a level of QoS and ease of application integration in a wired environment. In a MANET environment, the performance of this protocol degrades significantly because it is likely to mistake losses induced by the wireless media as network congestion and deploy congestion control mechanisms inappropriately. User Datagram Protocol (UDP) may be suitable for multicast data but does not provide the reliability or ordering of packets. If this protocol is selected, it becomes the responsibility of the application to provide the required QoS features. Stream Control Transmission Protocol (SCTP) is a message based protocol that is a hybrid of UDP and TCP. It provides QoS but it is not as well-known or commonly used. Further investigation will be required to determine whether it or any other protocol would better suit the needs of the application.

TRAFFIC ASSUMPTIONS

On a related topic, most wired network applications assume data traffic is unicast, usually between a client and a server. Unicast utilizes a reliable transport (TCP) which simplifies application functionality. However, as discussed in the previous section, additional considerations must be made when using TCP. If application architecture is server-less, data must be shared to multiple nodes and be transmitted via multicast (and UDP).

NETWORK SERVICES

Finally, applications are free to use the networking services provided by the JTR sets. As discussed earlier, JTRS networking services provide a set of services that have been selected for tactical wireless communications. This is a limited set from the number of services available to an application operating in a wired environment. Currently the JTRS networking services do not include file transfer protocol (FTP), secure shell, or Lightweight Directory Access Protocol (LDAP). An application must be tailored to use the available services on the JTR set.

SUMMARY

JTRS is in the process of delivering significant new capability to the warfighter. The JTRS networking waveforms and networking services provide significant capabilities as stand alone applications but can also be exploited by applications to provide even greater services to warfigher. As discussed, applications must understand the capabilities of this JTRS networking infrastructure and the unique characteristics that form the tactical wireless environment to effectively operate in it.

REFERENCES

[1] R. North, N. Browne, L. Schiavone, “Joint Tactical Radio System – Connecting the GIG to the Tactical Edge”, 23 October 2006.

[2] R. North, “Enabling the Warfighter for Joint Vision 2020 - 2008 C4ISR Symposium”, 22 April 2008.

[3] CAPT J. Hoyle, “Delivering Mobile Ad Hoc Networking to the Joint Warfighter – 2008 C4ISR Symposium”, 22 April 2008.

[4] S. Corson, J. Macker, “Mobile Ad hoc Networking: (MANET): Routing Protocol Performance Issues and Evaluation Considerations, January 1999.

BIOGRAPHIES

Donald R. Stephens, PhD, JPEO JTRS – San Diego is the Standards Manager. His team is responsible for the establishment and standardization of the JTRS infrastructure. They are responsible for the various standards defined by the JTRS program including the Software Communications Architecture (SCA), Application Programming Interfaces (APIs), software standard, and others. He has development experience with three software radios: the Digital Modular Radio (DMR), the Joint Tactical Terminal (JTT), and the Airborne Integrated Terminal Group (AITG). He has extensive experience in multiple communications and radar receiver systems with companies such as Raytheon E-Systems, McDonnell Douglas, Emerson Electric, and Scientific Atlanta. He has participated in all technology facets of software radio design such as Radio Frequency (RF), Digital Signal Processing (DSP), distributed computing, security, and networking.

Cinly Magsombol is currently serving as a Senior Engineer for the JPEO JTRS Standards team. Her work includes developing specifications and standards for the JTRS enterprise. Ms. Magsombol has been involved in JTRS since 2003 and has a Bachelor of Science degree in Electrical Engineering from the University of California, San Diego.

Norman Browne is a Principal with SRA International, Inc. He has been with SRA six years and is currently assigned to the JTRS Network Enterprise Domain (NED) as a senior systems engineer under the NED Chief Engineer. He completed undergraduate studies at the California State University, San Bernardino (’81, BA) and graduate studies at the Claremont Graduate University (’89, MS). He has over 20 years of software development and management experience in the commercial and public sectors.